LM5160 Fly-Buck (Isolated Buck) User’s Guide

User's Guide

Literature Number: SNVU408A
October 2014–Revised February 2015

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LM5160 User's Guide

1 Introduction

The LM5160NDNTFBKEVM evaluation module (EVM) helps designers evaluate the operation and performance of the LM5160 in the Fly-Buck™ (isolated buck) configuration. The Fly-Buck topology is derived from the synchronous buck topology by replacing the buck inductor with a coupled inductor (transformer) to produce both primary (non-isolated) and secondary (isolated) outputs. This user guide details the specification of the EVM and includes complete application schematic, bill of materials (BOM), setup instructions, and performance curves. The LM5160 device name is used generically throughout this document and represents both the LM5160 and LM5160A unless stated otherwise. The only difference between the two is the ability to connect an external voltage source to the VCC pin of the LM5160A.

2 Background

The application schematic is designed to operate from a 24 V nominal bus with the input voltage ranging from 18 V to 32 V. It is capable of supplying 12 V with the secondary load rated to 400 mA at the isolated output. The nominal switching frequency is 300 kHz. The high side and low side MOSFETs are integrated in the LM5160 and LM5160A. The EVM is designed to demonstrate a small solution size in the WSON-12 lead-less package for low power isolated bias applications.

Table 1. Default Board Specification with LM5160

INPUT	FREQUENCY	VOUT1	ISOLATED V_{OUT}	I_{OUT}
VIN = 18 V – 32 V	300 kHz	8 V	12 V	0 – 400 mA

The EVM can also be arranged with an alternate configuration shown in Table 2 using some simple modifications. The changes in the BOM for the alternate configuration is shown in Table 4. This configuration is optimized for lower power, high efficiency application.

Table 2. Alternate Configuration with LM5160

INPUT	FREQUENCY	VOUT1	ISOLATED V_{OUT}	I_{OUT}
VIN = 18 V – 32 V	160 kHz	10 V	15 V	0-200 mA

3 Setup

This section describes the connectors and test-points on the EVM as well as how to properly connect, setup and use the LM5160DNTFBKEVM with the LM5160.

3.1 Input/Output Connector Description

J1 – Output is the isolated output voltage for the converter. The terminal block provides V_{OUTISO} (+) and isolated ground (-) connection to allow the user to attach the EVM to a load.

J2 – Output is the primary non-isolated regulated output voltage for the converter. The terminal block provides VOUT1 (+) and ground (-) connection to allow the user to attach the EVM to a load.

J3 – Input is the power input terminal for the converter. The terminal block provides input V_{IN}(+) and ground (-) connections to allow the user to attach the EVM to a power supply.

TP1 – (SW1) allows the user to connect a scope probe to observe the primary side switching node of the converter.

3.2 Operation

For proper operation of the Fly-Buck converter, gradually increase the input voltage applied across J3. The load on the secondary output (**J1**) with primary output (**J2**) unloaded, should not exceed 400 mA which corresponds to 30 Ω. If the primary is loaded, the combined load on the two outputs should not exceed 600 mA. The coupled inductor (transformer) **T1** utilized in this board is optimized for small solution size and is not rated for the peak current limit of LM5160. If short circuit protection is required, **T1** should be replaced with a coupled inductor (flyback transformer) with primary side saturation current rating greater than the peak current limit of LM5160.

When the input voltage exceeds approximately 18 V, the primary and secondary outputs (**J2** and **J1**) power up to approximately 8 V and 12 V respectively.

The frequency of operation is set using the R_{ON} resistor (R7)

$$f_{SW} = \frac{V_{OUT1}}{1 \times 10^{-10} \times R_{ON}} \quad (1)$$

The primary output voltage can be set with the feedback divider resistors R8 and R9, using the following equation:

$$V_{OUT1} = \left(1 + \frac{R8}{R9}\right) \times 2\ V \quad (2)$$

The secondary output is related to the primary output voltage by the transformer turns ratio:

$$V_{OUTISO} = V_{OUT1} \times \frac{N2}{N1} - V_F \quad (3)$$

where N2/N1 is the turns ratio and V_F is the forward voltage drop of the secondary rectifier diode. There is some additional drop because of the leakage inductance and resistance of windings.

4 Board Layout

Figure 1, Figure 2, and Figure 3 show the board layout for the LM5160DNTFBKVM PCB. The WSON package offers an exposed thermal pad for enhanced thermal performance. The IC must be soldered properly to the copper landing on the PCB for optimal performance. The EVM is a two layer board.

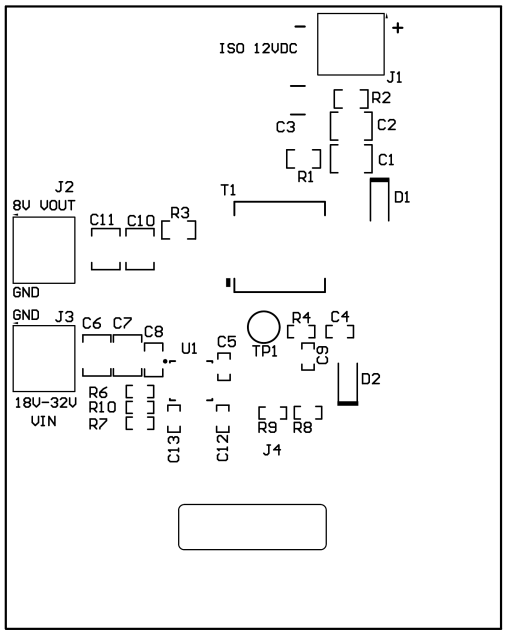

Figure 1. Top Assembly Layer

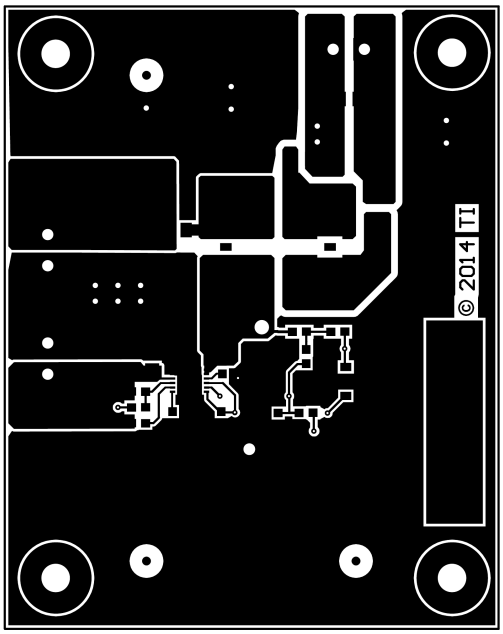

Figure 2. Top Copper

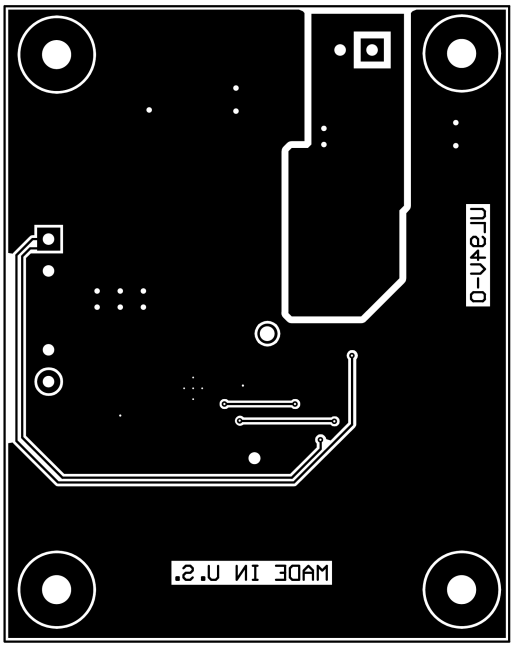

Figure 3. Bottom Copper

5 Schematic

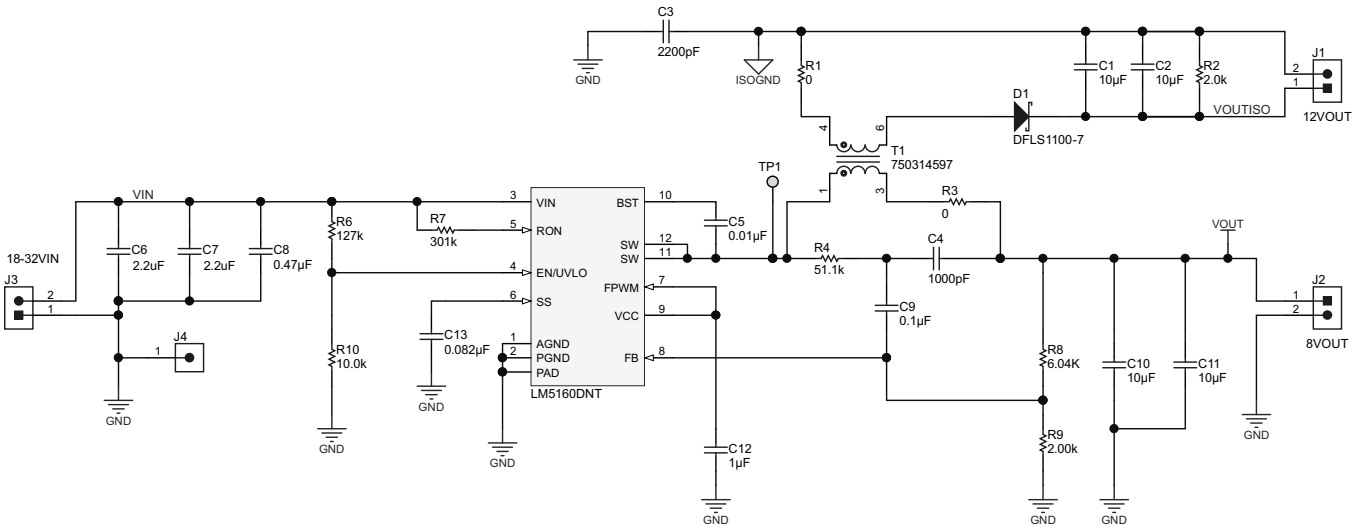

Figure 4. LM5160 Fly-Buck EVM Schematic

Figure 5 below shows the Fly-buck configuration using LM5160A with the VCC being powered from the VOUT (8VOUT, Primary) through diode D2 for improved efficiency requirements. When evaluating the LM5160A, the designer can use the standard LM5160DNTFBKEVM by simply replacing the LM5160 IC with the LM5160A. No other components on board need to be replaced or removed. In the standard EVM, when used with the LM5160, the placeholder for diode D2, as given in Figure 1, must remain unpopulated under all cases. For more information about the difference between the LM5160A and the LM5160, please refer to the LM5160 Datasheet (SNVSA03).

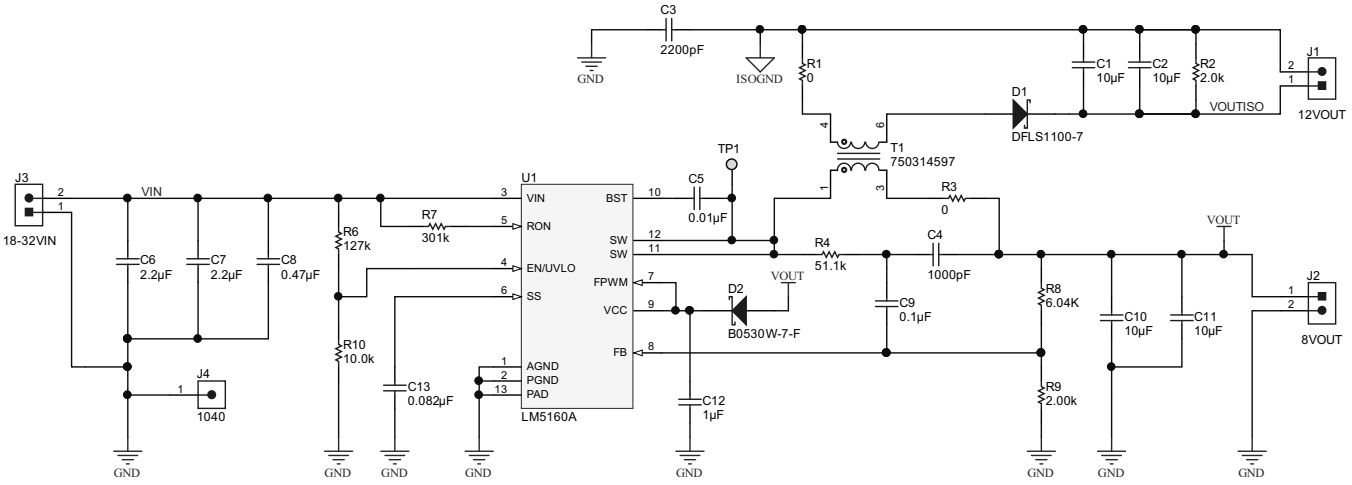

Figure 5. Fly-Buck Schematic with LM5160A

6 Bill of Materials

Table 3. LM5160DNTFBKEVM Bill of Materials for 300 kHz Configuration

COUNT	REF DES	DESCRIPTION	SIZE	MFR	PART NUMBER
4	C1, C2, C10, C11	CAP, CERM, 10 µF, 35 V, ±10%, X7R,	1210	MuRata	GRM32ER7YA106KA12L
1	C3	CAP, CERM, 2200 pF, 2000 V, ±10%, X7R	1812	TDK	C4532X7R3D222K
1	C4	CAP, CERM, 1000 pF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C102KA01D
1	C5	CAP, CERM, 0.01 µF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C103KA01D
2	C6, C7	CAP, CERM, 2.2 µF, 100 V, X7R, 10%	1210	Murata	GRM32ER72A225KA35K
1	C8	CAP, CERM, 0.47 µF, 100 V, ±10%, X7R	805	MuRata	GRM21BR72A474KA73L
1	C9	CAP, CERM, 0.1 µF, 25 V, ±5%, X7R	603	AVX	06033C104JAT2A
1	C12	CAP, CERM, 1 µF, 16 V, ±10%, X7R	603	TDK	C1608X7R1C105K
1	C13	CAP, CERM, 0.082 µF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C823KA01D
1	D1	Diode, Schottky, 100 V, 1 A	PowerDI123	Diodes Inc.	DFLS1100-7
1	D2	Diode, Schottky, 30 V, 0.5 A (LM5160A only)	SOD-123	Diodes Inc.	B0530W-7-F(Unpopulated)
3	J1, J2, J3	Terminal Block, 6 A, 3.5 mm Pitch, 2-Pos, TH	7.0x8.2x6.5 mm	On-Shore Technology	ED555/2DS
2	R1, R3	RES, 0 Ω, 5%, 0.125 W	805	Vishay-Dale	CRCW08050000Z0EA
1	R2	RES, 2.0 kΩ, 5%, 0.125 W	805	Vishay-Dale	CRCW08052K00JNEA
1	R4	RES, 51.1 kΩ, 1%, 0.1 W	603	Yageo	RC0603FR-0751K1L
1	R6	RES, 127 kΩ, 1%, 0.1 W	603	Yageo	RC0603FR-07127KL
1	R7	RES, 301 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW0603301KFKEA
1	R8	RES, 6.04 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW06036K04FKEA
1	R9	RES, 2.00 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW06032K00FKEA
1	R10	RES, 10.0 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW060310K0FKEA
1	T1	Transformer, 60 uH, SMT, 0.840 A	13.36x8.64x 10.16 mm	Wurth Elektronik	750314597
1	TP1	Test Point, Multipurpose, Yellow, TH	Testpoint	Keystone	5014
1	U1	IC, PWM, COT Regulator	DNT0012B	Texas Instruments	LM5160DNT

Table 4. Bill of Materials for Alternate Configuration

COUNT	REF DES	DESCRIPTION	SIZE	MFR	PART NUMBER
4	C1, C2, C10, C11	CAP, CERM, 10 µF, 35 V, ±10%, X7R,	1210	MuRata	GRM32ER7YA106KA12L
1	C3	CAP, CERM, 2200 pF, 2000 V, ±10%, X7R	1812	TDK	C4532X7R3D222K
1	C4	CAP, CERM, 1000 pF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C102KA01D
1	C5	CAP, CERM, 0.01 µF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C103KA01D
2	C6, C7	CAP, CERM, 2.2 µF, 100 V, X7R, 10%	1210	Murata	GRM32ER72A225KA35K
1	R8	RES, 8.2 kΩ, 1%, 0.1 W, 0603	603	Standard	Standard
1	R7	RES, 698 kΩ, 1%, 0.1 W, 0603	603	Standard	Standard
1	C4	CAP, CERM, 3300 pF, 16 V, ±10%, X7R	603	Standard	Standard
1	R2	RES, 5.1 kΩ, 5%, 0.125 W	805	Standard	Standard
1	D1	Diode, Schottky, 60 V, 1A	PowerDI123	Diodes Inc.	DFLS160-7
1	C8	CAP, CERM, 0.47 µF, 100 V, ±10%, X7R	805	MuRata	GRM21BR72A474KA73L
1	C9	CAP, CERM, 0.1 µF, 25 V, ±5%, X7R	603	AVX	06033C104JAT2A
1	C12	CAP, CERM, 1 µF, 16 V, ±10%, X7R	603	TDK	C1608X7R1C105K
1	C13	CAP, CERM, 0.082 µF, 16 V, ±10%, X7R	603	MuRata	GRM188R71C823KA01D
1	D1	Diode, Schottky, 100 V, 1 A	PowerDI123	Diodes Inc.	DFLS1100-7
1	D2	Diode, Schottky, 30 V, 0.5 A (LM5160A only)	SOD-123	Diodes Inc.	B0530W-7-F(Unpopulated)
3	J1, J2, J3	Terminal Block, 6 A, 3.5 mm Pitch, 2-Pos, TH	7.0x8.2x6.5 mm	On-Shore Technology	ED555/2DS
2	R1, R3	RES, 0 Ω, 5%, 0.125 W	805	Vishay-Dale	CRCW08050000Z0EA
1	R4	RES, 51.1 kΩ, 1%, 0.1 W	603	Yageo	RC0603FR-0751K1L
1	R6	RES, 127 kΩ, 1%, 0.1 W	603	Yageo	RC0603FR-07127KL
1	R7	RES, 301 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW0603301KFKEA
1	R9	RES, 2.00 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW06032K00FKEA
1	R10	RES, 10.0 kΩ, 1%, 0.1 W	603	Vishay-Dale	CRCW060310K0FKEA
1	T1	Transformer, 60 uH, SMT, 0.840 A	13.36x8.64x 10.16 mm	Wurth Elektronik	750314597
1	TP1	Test Point, Multipurpose, Yellow, TH	Testpoint	Keystone	5014
1	U1	IC, PWM, COT Regulator	DNT0012B	Texas Instruments	LM5160DNT

7 Performance Curves with LM5160

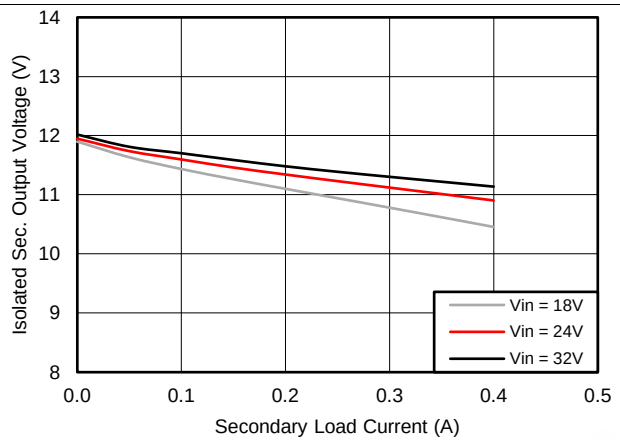

Figure 6. Line and Load Regulation

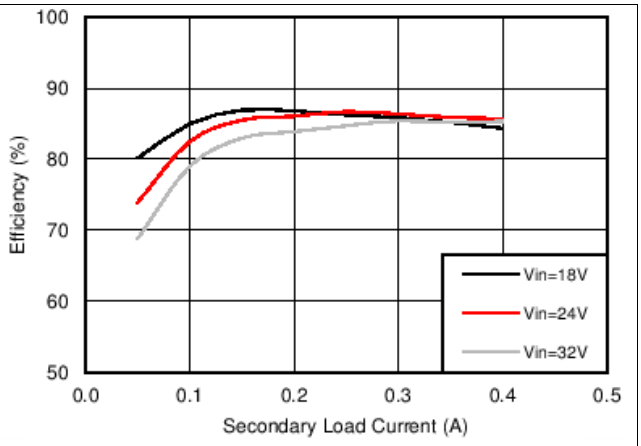

Figure 7. Efficiency vs I_{OUT2} with Default Board Configuration

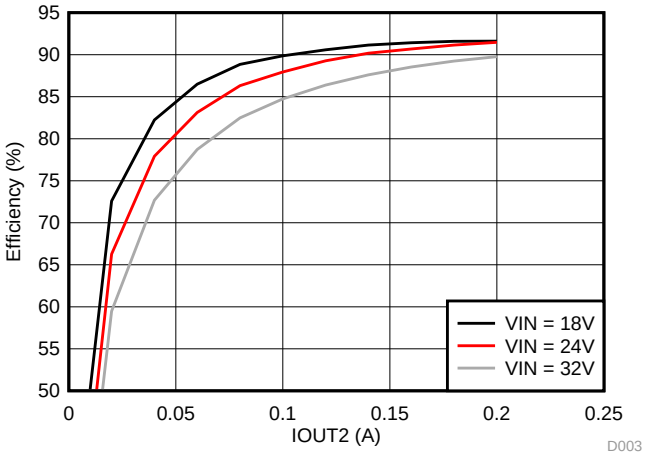

Figure 8. Efficiency vs I_{OUT2} with Alternate Configuration

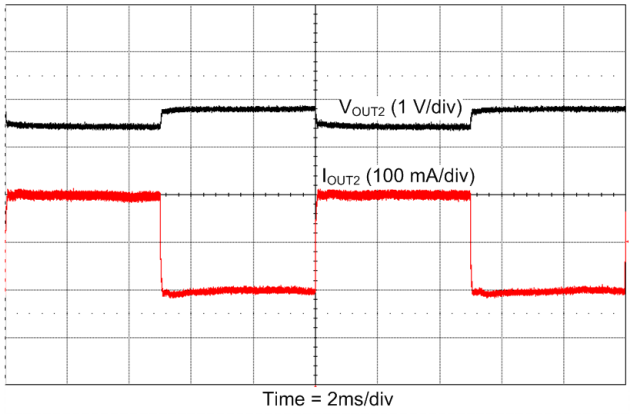

Figure 9. Load Transient at V_{IN} = 24 V I_{OUT2} = 100 mA to 300 mA

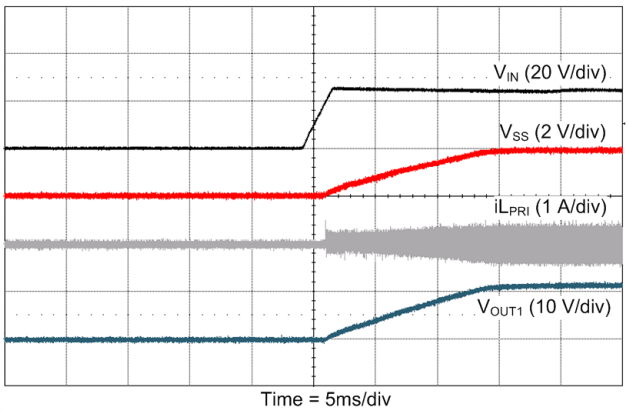

Figure 10. V_{IN} Startup Waveform at I_{OUT2} = 200 mA and I_{OUT1} = 0 A

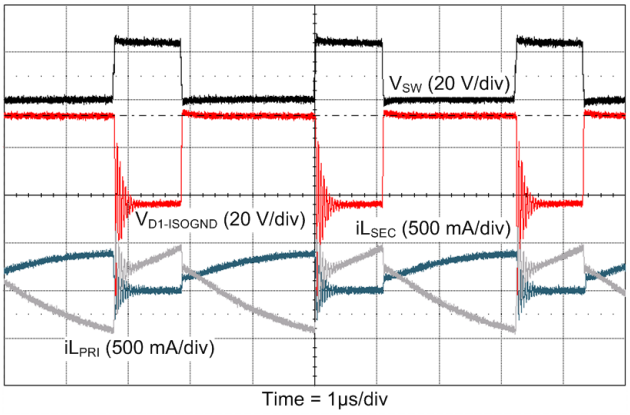

Figure 11. Primary Switch Node at V_{IN} = 24 V and I_{OUT2} = 200 mA

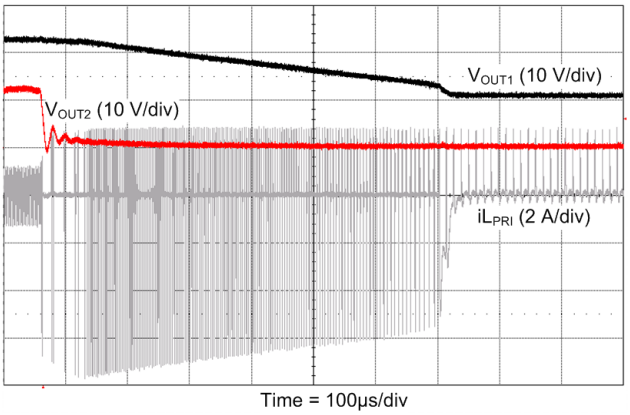

Figure 12. Secondary-side Short at I_{OUT2} = 600 mA and I_{OUT1} = 200mA (Tx: Wurth Elektronik #: 744873220)

Revision History

Changes from Original (October 2014) to A Revision **Page**

- Added LM5160A to Background 4
- Added new paragraph for LM5160A 6
- Added D2 Schottky Diode information to Bill of Materials 7
- Added D2 Schottky Diode information to Bill of Materials for Alternate Configuration 8

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

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2 *Limited Warranty and Related Remedies/Disclaimers*:

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   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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Last updated 10/2025